SOLAR/1024-79/04

Monthly Performance Report

LIVING SYSTEMS

APRIL 1979

U.S. Department of Energy

National Solar Heating and Cooling Demonstration Program

National Solar Data Program

MONTHLY PERFORMANCE REPORT

LIVING SYSTEMS

APRIL 1979

I. SYSTEM DESCRIPTION

The Living Systems site is a single-family residence in Davis, California. The home has approximately 1700 square feet of conditioned space. The solar energy system consists of two independently controlled systems: an active system for preheating domestic-hot-water (DHW) and a passive system for space heating the home.

The active solar DHW system has an array of flat-plate collectors with a gross area of 46 square feet. The array faces south at an angle of 45 degrees to the horizontal. Potable city water is the transfer medium used throughout the system. In the event of freezing and no insolation, the controller drains the water from the collectors. When water in the collector is sufficiently warmer than the water in the preheat storage tank, the controller starts the circulation between the preheat tank and the collector. The preheat tank holds 82-gallons of water which is supplied, on demand, to a conventional 20-gallon DHW tank. When the water preheated by solar energy is not hot enough to satisfy the hot water load, a natural gas burner in the DHW tank provides auxiliary energy for water heating. The system is shown schematically in Figure 1.

The passive solar space heating system is of the direct-gain type illustrated schematically in Figure 2. Incident solar energy is admitted to the building through both the large south-facing vertical windows (approximately 200 square feet) and the overhead skylight (approximately 80 square feet at 60 degrees from the horizontal). Manually operated insulating curtains provide insulation during the night and sunless days for the south-facing collector windows. Manually operated insulating shutters also provide night insulation for the skylight glazing and are aluminum coated to provide reflection to the space below when open. Solar energy storage is provided by steel tubes that contain approximately 3600 gallons of water. The tubes are painted blue and placed near the south window wall and under the skylight. Additional

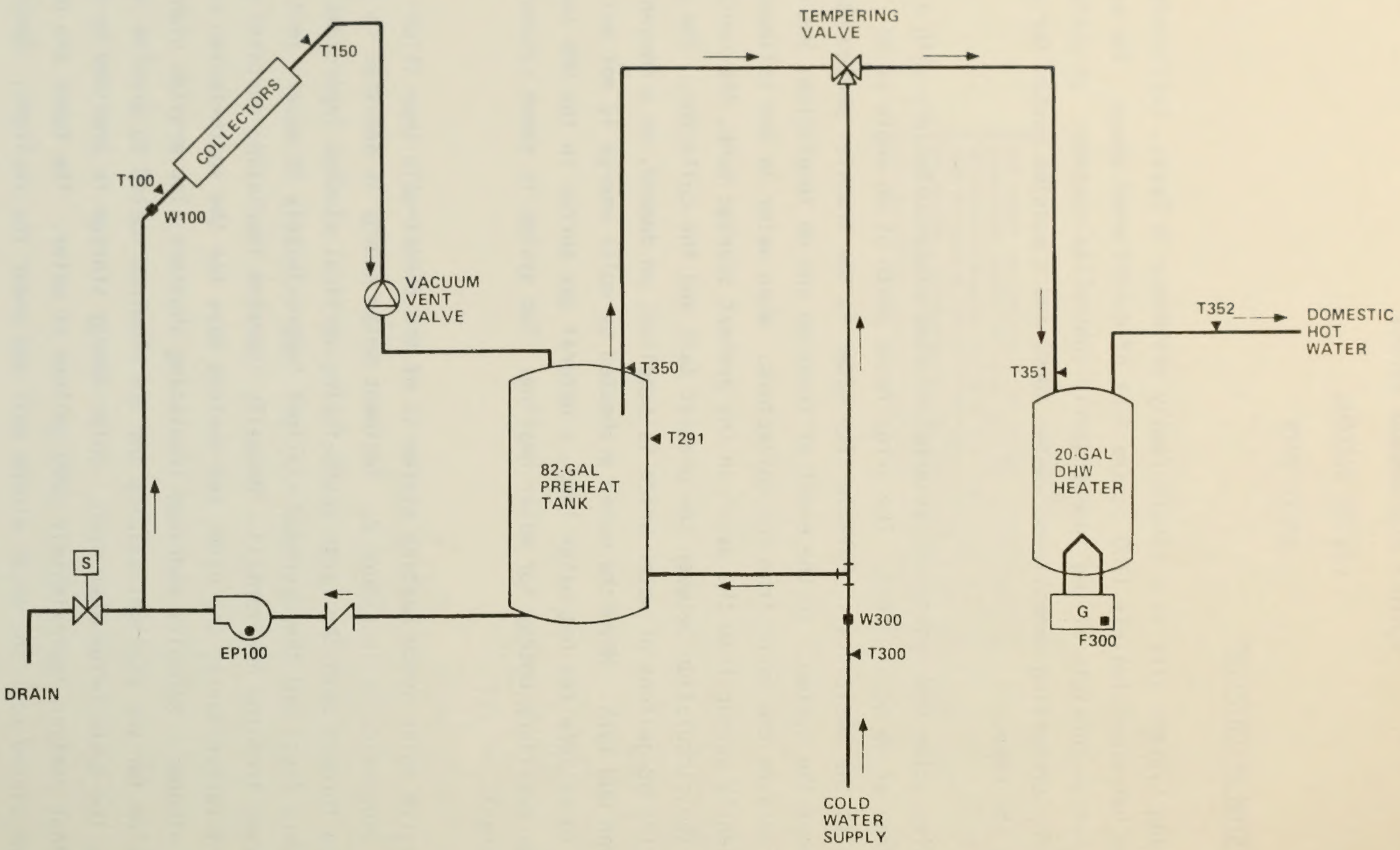

Figure 1. LIVING SYSTEMS ACTIVE SOLAR DOMESTIC HOT WATER SYSTEM SCHEMATIC

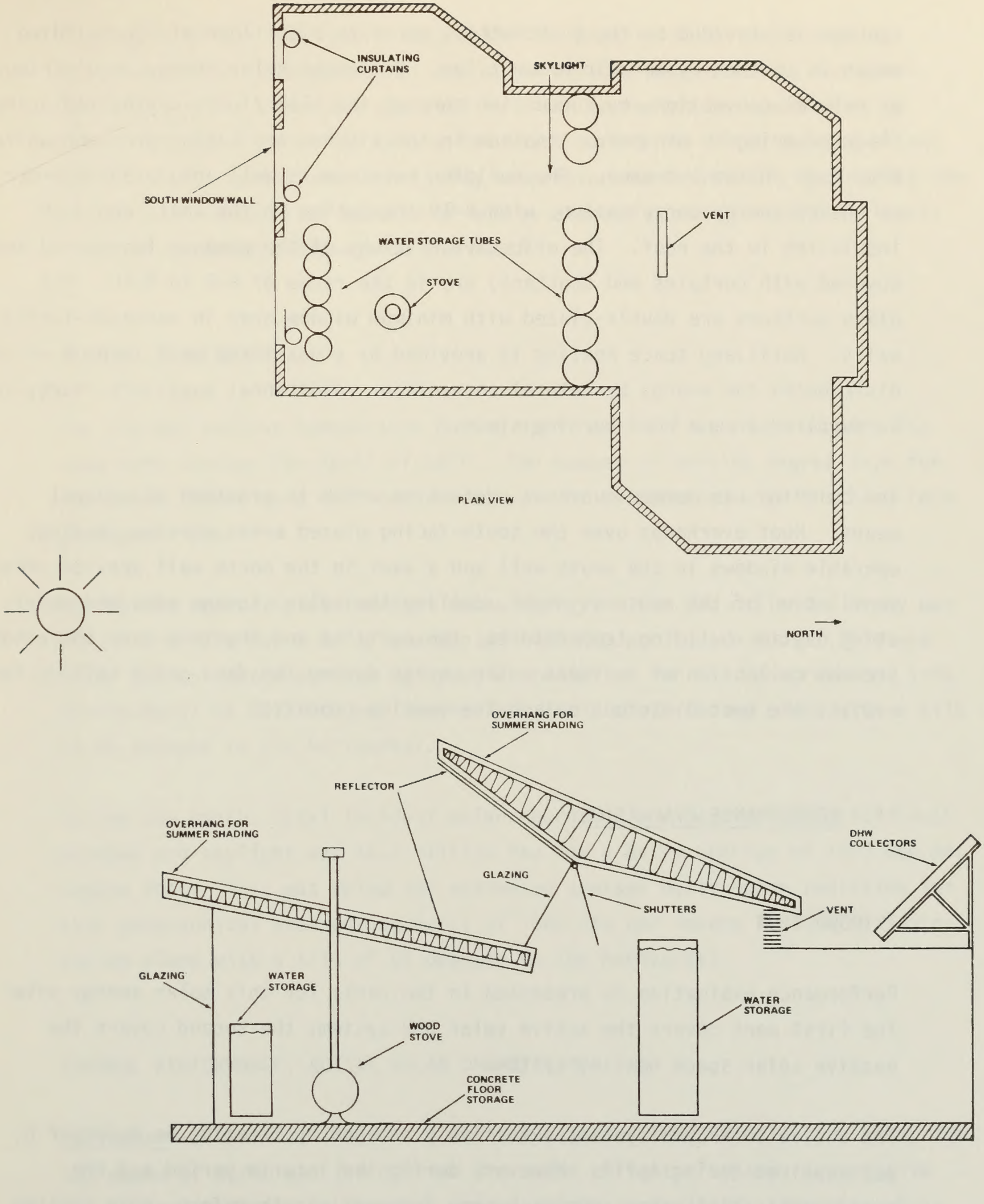

Figure 2. LIVING SYSTEMS PASSIVE SPACE HEATING SYSTEM

storage is provided by the 6-inch-thick concrete slab floor of the building which is covered by ceramic brown tiles. Collected solar energy is distributed by natural convection, by conduction through the slab floor, and by radiation. Floor covering is minimal: linoleum in the kitchen and eating area and white shag rugs in two bedrooms. The building envelope is well insulated in order to ensure energy conservation, with R-19 insulation in the walls and R-30 insulation in the roof. The effective R-values of the windows (uncovered and covered with curtains and shutters) are in the range of R-2 to R-10. All glass surfaces are double-glazed with minimum window area in nonsouth-facing walls. Auxiliary space heating is provided by a gas-fired wall furnace which distributes the energy by natural convection. Additional auxiliary energy can be supplied from a wood-burning stove.

The building has summer overheat protection which is provided by several means: Roof overhangs over the south-facing glazed areas provide shading; operable windows in the south wall and a vent in the north wall provide cross-ventilation of the house at night, cooling the solar storage mass and moderating daytime building temperatures; the curtains and shutters over the windows prevent collection of incident solar energy during the day; and a ceiling fan assists the heat distribution and the venting process.

II. PERFORMANCE EVALUATION

INTRODUCTION

Performance evaluation is presented in two parts for this solar energy site: The first part covers the active solar DHW system; the second covers the passive solar space heating system.

The active solar DHW system, extensively damaged by freezing on December 8, was repaired during April. However, during the interim period and the repair activities, some sensors became inoperative; therefore, only limited information is available on this system. The active solar DHW system satisfied

14 percent of the hot water load, while the passive solar space heating system satisfied 100 percent of the space heating demand during the month. The wood-burning stove was operated in order to reduce the space heating load, but this occured for only a few hours during the first morning of the month. Daily variations in building temperature were minimal, indicating the presence of substantial amounts of energy storage capacity. Comfort levels remained reasonable throughout the month.

WEATHER CONDITIONS

The average ambient temperature during April was 57°F as compared with the long-term average for April of 58°F. The number of heating degree-days for the month (based on a 65°F reference) was 341 as compared with the long-term average of 227.

During the month, total incident solar energy on the DHW collector array was 2.0 million Btu for a daily average of 1485 Btu per square foot. This was below the estimated average daily solar radiation for this geographical area during April of 2011 Btu per square foot for a south-facing plane with a tilt of 45 degrees to the horizontal.

During the month, total incident solar energy on the passive collector south windows and skylight was 10.3 million Btu for a daily average of 1263 Btu per square foot. This was below the estimated average daily solar radiation for this geographical area during April of 1800 Btu per square foot for a south-facing plane with a tilt of 60 degrees to the horizontal.

THERMAL PERFORMANCE, ACTIVE SOLAR DHW SYSTEM

Collector - The total incident solar radiation on the DHW collector array for the month of March was 2.0 million Btu. The collector system, inoperative due to freeze damage in December, was repaired on April 23. However, while the collectors were inoperative during the first part of the month, the storage, pipes, sensors, etc. were still working. There was leakage of 0.024

million Btu from the passive heating system into the DHW preheat system. When the system was repaired on April 23, the collector pump sensor was made inoperative and the auxiliary fuel sensor load already failed on March 4. In addition to the leakage, solar energy was collected for a total of 0.216 million Btu. The effective solar collector array efficiency was 11 percent, based on total insolation. The operating energy required by the collector loop was not measurable, despite the zeroes indicated in the printed report.

DHW Load - The DHW system consumed 0.216 million Btu of solar energy. The hot water load was 1.6 million Btu. The passive system spill-over and the energy collected after the system was repaired resulted in fossil fuel energy savings of 0.36 million Btu. A daily average of 113 gallons of DHW was consumed at an average temperature of 125°F delivered from the tank.

THERMAL PERFORMANCE, PASSIVE SOLAR SPACE HEATING SYSTEM

The total incident solar radiation on the collector windows for the month of April was 10.3 million Btu. The total collected solar energy for the month of April was 3.9 million Btu. The total solar energy delivered to the space heating load was 3.7 million Btu, resulting in a collector array efficiency of 36 percent, based on total incident insolation. Auxiliary thermal energy was not used to satisfy the space heating load, and the pilot light was turned off to save energy. The result was a fossil fuel energy savings of 6.1 million Btu. The solar fraction of this load was 100 percent. The average storage temperature for the month was 68°F.

During the early morning of the first day in April, the wood-burning stove was used to satisfy a measurable amount of the building load. During April, this renewable energy was only 0.042 million Btu. Assuming a wood-stove energy conversion efficiency of 30 percent, this 0.042 million Btu is less than 1 percent of a cord of dry hardwood (such as oak). In terms of the savings of nonrenewable energy, the renewable thermal energy derived from the wood was equivalent to over 0.07 million Btu of fossil fuel energy.

The interior comfort level was measured at 69°F in both zone 1, the south end of the building, and zone 2, the north end. A slight daily temperature difference is usually expected because comfort zone 2 is heated by conduction through the slab and walls, and by convection and infiltration through the doors.

OBSERVATIONS

During the month of April, the passive solar system completely satisfied the space heating with enough energy left over to raise the storage temperature by 2°F. The woodburning stove was used a few hours during the first day of the month. With the space heating load reduced by milder weather, operation of the reflective (and insulating) shutters and curtains was not as critical, and the operational to incident solar energy went down. This resulted in a lower solar conversion efficiency. The curtains are not yet fully operational. With reasonably large uncurtained windows in the northeast bedroom, some afternoon overheating has occurred. The DHW system was repaired during the month. The monthly average DHW solar fraction was 14 percent for the last seven days of the month; after the repairs, the solar fraction jumped to 41 percent.

Computed comfort levels inside the building were very stable during the entire month in both zones of the building, varying at most by 1°F over the daily averages.

The fuel meter and collector pump sensors were inoperative and the water meter read high. Installation of insulating curtains has not been completed by the owner.

ENERGY SAVINGS

The solar energy systems yielded a total fossil fuel energy savings of 6.5 million Btu. The DHW system provided an estimated fossil fuel energy savings of 0.36 million Btu, while the space heating system contributed a fossil fuel energy savings of 6.1 million Btu.

III. ACTION STATUS

Boeing has been requested to inspect the sensor anomalies.

SOLAR HEATING AND COOLING DEMONSTRATION PROGRAM

MONTHLY REPORT
SITE SUMMARY

SITE: LIVING SYSTEMS (159-1) DAVIS, CALIFORNIA SOLAR/1046-79/04
REPORT PERIOD: APRIL,1979

SITE/SYSTEM DESCRIPTION:
THE LIVING SYSTEMS SOLAR DOMESTIC HOT WATER SYSTEM PROVIDES PREHEAT TO THE BUILDING DOMESTIC HOT WATER SYSTEM . THIS ACTIVE SYSTEM USES FLAT PLATE COLLECTORS (46 SQ.FT.) TO HEAT WATER DIRECTLY IN A 82 GALLON STORAGE TANK. AUXILIARY HOT WATER ENERGY IS PROVIDED BY NATURAL GAS IN THE 20 GALLON HOT WATER HEATER.

GENERAL SITE DATA:

INCIDENT SOLAR ENERGY	2.049	MILLION BTU
	44544	BTU/SQ.FT.
COLLECTED SOLAR ENERGY	*	MILLION BTU
	*	BTU/SQ.FT.
AVERAGE AMBIENT TEMPERATURE	57	DEGREES F
AVERAGE BUILDING TEMPERATURE	68	DEGREES F
ECSS SOLAR CONVERSION EFFICIENCY	0.11	
ECSS OPERATING ENERGY	0.000	MILLION BTU
TOTAL SYSTEM OPERATING ENERGY	0.000	MILLION BTU
TOTAL ENERGY CONSUMED	*	MILLION BTU

SUBSYSTEM SUMMARY:

	HOT WATER	HEATING	COOLING	SYSTEM TOTAL
LOAD	1.572	N.A.	N.A.	1.572 MILLION BTU
SOLAR FRACTION	*	N.A.	N.A.	* PERCENT
SOLAR ENERGY USED	0.216	N.A.	N.A.	0.216 MILLION BTU
OPERATING ENERGY	N.A.	N.A.	N.A.	0.000 MILLION BTU
AUX. THERMAL ENERGY	*	N.A.	N.A.	* MILLION BTU
AUX. ELECTRIC FUEL	N.A.	N.A.	N.A.	N.A. MILLION BTU
AUX. FOSSIL FUEL	*	N.A.	N.A.	* MILLION BTU
ELECTRICAL SAVINGS	N.A.	N.A.	N.A.	0.000 MILLION BTU
FOSSIL SAVINGS	0.359	N.A.	N.A.	0.359 MILLION BTU

SYSTEM PERFORMANCE FACTOR: *

* DENOTES UNAVAILABLE DATA
@ DENOTES NULL DATA
N.A. DENOTES NOT APPLICABLE DATA

REFERENCE: USER'S GUIDE TO THE MONTHLY PERFORMANCE REPORT OF THE NATIONAL SOLAR DATA PROGRAM,FEBRUARY 28,1978, SOLAR/0004-78/18

SOLAR HEATING AND COOLING DEMONSTRATION PROGRAM

MONTHLY REPORT
SITE SUMMARY

SITE: LIVING SYSTEMS (159-1) DAVIS, CALIFORNIA — SOLAR/1046-79/04
REPORT PERIOD: APRIL,1979

SITE/SYSTEM DESCRIPTION:
THE LIVING SYSTEMS SOLAR DOMESTIC HOT WATER SYSTEM PROVIDES PREHEAT TO THE BUILDING DOMESTIC HOT WATER SYSTEM . THIS ACTIVE SYSTEM USES FLAT PLATE COLLECTORS (46 SQ.FT.) TO HEAT WATER DIRECTLY IN A 82 GALLON STORAGE TANK. AUXILIARY HOT WATER ENERGY IS PROVIDED BY NATURAL GAS IN THE 20 GALLON HOT WATER HEATER.

GENERAL SITE DATA:

INCIDENT SOLAR ENERGY	2.162	GIGA JOULES
	505842	KJ/SQ.M.
COLLECTED SOLAR ENERGY	*	GIGA JOULES
	*	KJ/SQ.M.
AVERAGE AMBIENT TEMPERATURE	14	DEGREES C
AVERAGE BUILDING TEMPERATURE	20	DEGREES C
ECSS SOLAR CONVERSION EFFICIENCY	0.11	
ECSS OPERATING ENERGY	0.000	GIGA JOULES
TOTAL SYSTEM OPERATING ENERGY	0.000	GIGA JOULES
TOTAL ENERGY CONSUMED	*	GIGA JOULES

SUBSYSTEM SUMMARY:

	HOT WATER	HEATING	COOLING	SYSTEM TOTAL	
LOAD	1.659	N.A.	N.A.	1.659	GIGA JOULES
SOLAR FRACTION	*	N.A.	N.A.	*	PERCENT
SOLAR ENERGY USED	0.228	N.A.	N.A.	0.228	GIGA JOULES
OPERATING ENERGY	N.A.	N.A.	N.A.	0.000	GIGA JOULES
AUX. THERMAL ENG	*	N.A.	N.A.	*	GIGA JOULES
AUX. ELECTRIC FUEL	N.A.	N.A.	N.A.	N.A.	GIGA JOULES
AUX. FOSSIL FUEL	*	N.A.	N.A.	*	GIGA JOULES
ELECTRICAL SAVINGS	N.A.	N.A.	N.A.	0.000	GIGA JOULES
FOSSIL SAVINGS	0.379	N.A.	N.A.	0.379	GIGA JOULES

SYSTEM PERFORMANCE FACTOR: *

* DENOTES UNAVAILABLE DATA
@ DENOTES NULL DATA
N.A. DENOTES NOT APPLICABLE DATA

REFERENCE: USER'S GUIDE TO THE MONTHLY PERFORMANCE REPORT OF THE NATIONAL SOLAR DATA PROGRAM,FEBRUARY 28,1978, SOLAR/0004-78/18

SOLAR HEATING AND COOLING DEMONSTRATION PROGRAM

MONTHLY REPORT
ENERGY COLLECTION AND STORAGE SUBSYSTEM (ECSS)

SITE: LIVING SYSTEMS (159-1) DAVIS, CALIFORNIA SOLAR/1046-79/04
REPORT PERIOD: APRIL,1979

DAY OF MONTH	INCIDENT SOLAR ENERGY MILLION BTU	AMBIENT TEMP DEG-F	ENERGY TO LOADS MILLION BTU	AUX THERMAL TO ECSS MILLION BTU	ECSS OPERATING ENERGY MILLION BTU	ECSS ENERGY REJECTED MILLION BTU	ECSS SOLAR CONVERSION EFFICIENCY
1	0.091	55	0.001	N	0.000	N	0.011
2	0.092	57	0.001	O	0.000	O	0.016
3	0.085	58	0.001	T	0.000	T	0.015
4	0.085	59	0.001		0.000		0.013
5	0.065	56	0.002	A	0.000	A	0.025
6	0.031	52	0.001	P	0.000	P	0.023
7	0.092	57	0.001	P	0.000	P	0.013
8	0.073	58	0.001	L	0.000	L	0.019
9	0.084	56	0.002	I	0.000	I	0.022
10	0.083	54	0.001	C	0.000	C	0.014
11	0.064	60	0.001	A	0.000	A	0.019
12	0.079	58	0.001	B	0.000	B	0.014
13	0.088	60	0.001	L	0.000	L	0.011
14	0.084	61	0.001	E	0.000	E	0.013
15	0.078	62	0.002		0.000		0.020
16	0.025	55	0.001		0.000		0.054
17	0.046	53	0.001		0.000		0.020
18	0.078	52	0.001		0.000		0.017
19	0.083	53	0.001		0.000		0.015
20	0.073	56	0.000		0.000		0.007
21	0.067	59	0.001		0.000		0.021
22	0.035	56	0.001		0.000		0.037
23	0.059	56	0.019		*		0.318
24	0.071	56	0.028		*		0.399
25	0.052	60	0.008		*		0.152
26	0.002	58	0.002		*		0.771
27	0.085	60	0.038		*		0.443
28	0.080	61	0.031		*		0.390
29	0.047	60	0.023		*		0.494
30	0.073	58	0.041		*		0.560
SUM	2.049	-	0.216	N.A.	0.000	N.A.	-
AVG	0.068	57	0.007	N.A.	0.000	N.A.	0.105
NBS ID	Q001	N113			Q102		N111

* DENOTES UNAVAILABLE DATA.
@ DENOTES NULL DATA.
N.A. DENOTES NOT APPLICABLE DATA.

SOLAR HEATING AND COOLING DEMONSTRATION PROGRAM

MONTHLY REPORT
COLLECTOR ARRAY PERFORMANCE

SITE: LIVING SYSTEMS (159-1) DAVIS, CALIFORNIA SOLAR/1046-79/04
REPORT PERIOD: APRIL,1979

DAY OF MONTH	INCIDENT SOLAR ENERGY MILLION BTU	OPERATIONAL INCIDENT ENERGY MILLION BTU	COLLECTED SOLAR ENERGY MILLION BTU	DAYTIME AMBIENT TEMP DEG F	COLLECTOR ARRAY EFFICIENCY
1	0.091	0.000	*	64	*
2	0.092	0.000	*	68	*
3	0.085	0.000	*	70	*
4	0.085	0.000	*	70	*
5	0.065	0.000	*	*	*
6	0.031	0.000	*	57	*
7	0.092	0.000	*	68	*
8	0.073	0.000	*	70	*
9	0.084	0.000	*	66	*
10	0.083	0.000	*	66	*
11	0.064	0.000	*	70	*
12	0.079	0.000	*	72	*
13	0.088	0.000	*	71	*
14	0.084	0.000	*	75	*
15	0.078	0.000	*	74	*
16	0.025	0.000	*	59	*
17	0.046	0.000	*	58	*
18	0.078	0.000	*	63	*
19	0.083	0.000	*	66	*
20	0.073	0.000	*	68	*
21	0.067	0.000	*	71	*
22	0.035	0.000	*	63	*
23	0.059	*	*	62	*
24	0.071	*	*	67	*
25	0.052	*	*	70	*
26	0.002	*	*	60	*
27	0.085	*	*	68	*
28	0.080	*	*	72	*
29	0.047	*	*	71	*
30	0.073	*	*	69	*
SUM	2.049	0.000	*	-	-
AVG	0.068	0.000	*	67	*
NBSID	Q001		Q100		N100

* DENOTES UNAVAILABLE DATA.
@ DENOTES NULL DATA.
N.A. DENOTES NOT APPLICABLE DATA.

SOLAR HEATING AND COOLING DEMONSTRATION PROGRAM

MONTHLY REPORT
STORAGE PERFORMANCE

SITE: LIVING SYSTEMS (159-1) DAVIS, CALIFORNIA SOLAR/1046-79/04
REPORT PERIOD: APRIL,1979

DAY OF MONTH	ENERGY TO STORAGE MILLION BTU	ENERGY FROM STORAGE MILLION BTU	CHANGE IN STORED ENERGY MILLION BTU	STORAGE AVERAGE TEMP DEG F	STORAGE EFFICIENCY
1	*	0.000	N	N	N
2	*	0.001	O	O	O
3	*	0.001	T	T	T
4	*	0.001			
5	*	0.001	A	A	A
6	*	0.000	P	P	P
7	*	0.001	P	P	P
8	*	0.001	L	L	L
9	*	0.000	I	I	I
10	*	0.001	C	C	C
11	*	0.001	A	A	A
12	*	0.001	B	B	B
13	*	0.001	L	L	L
14	*	0.001	E	E	E
15	*	0.001			
16	*	0.001			
17	*	0.001			
18	*	0.001			
19	*	0.000			
20	*	0.000			
21	*	0.000			
22	*	0.001			
23	*	0.016			
24	*	0.028			
25	*	0.005			
26	*	0.001			
27	*	0.038			
28	*	0.031			
29	*	0.024			
30	*	0.042			
SUM	*	0.201	N.A.	-	-
AVG	*	0.007	N.A.	N.A.	N.A.
NBS ID	Q200	Q201	Q202		N108

* DENOTES UNAVAILABLE DATA.
@ DENOTES NULL DATA.
N.A. DENOTES NOT APPLICABLE DATA.

SOLAR HEATING AND COOLING DEMONSTRATION PROGRAM

MONTHLY REPORT
HOT WATER SUBSYSTEM

SITE: LIVING SYSTEMS (159-1) DAVIS, CALIFORNIA SOLAR/1046-79/04
REPORT PERIOD: APRIL,1979

DAY OF MON.	HOT WATER LOAD MILLION BTU	SOLAR FR.OF LOAD PER CENT	SOLAR ENERGY USED MILLION BTU	OPER ENERGY MILLION BTU	AUX THERMAL USED MILLION BTU	AUX ELECT FUEL MILLION BTU	AUX FOSSIL FUEL MILLION BTU	ELECT ENERGY SAVINGS MILLION BTU	FOSSIL ENERGY SAVINGS MILLION BTU	SUP. WAT. TEMP DEG F	HOT WAT. TEMP DEG F	HOT WATER USED GAL
1	0.061	*	0.001	N	*	N	*	N	0.002	67	123	120
2	0.064	*	0.001	O	*	O	*	O	0.002	65	125	127
3	0.065	*	0.001	T	*	T	*	T	0.002	65	128	117
4	0.046	*	0.001		*		*		0.002	66	137	82
5	0.061	*	0.002	A	*	A	*	A	0.003	67	116	149
6	0.026	*	0.001	P	*	P	*	P	0.001	67	126	52
7	0.047	*	0.001	P	*	P	*	P	0.002	67	132	88
8	0.061	*	0.001	L	*	L	*	L	0.002	66	133	125
9	0.045	*	0.002	I	*	I	*	I	0.003	67	129	85
10	0.054	*	0.001	C	*	C	*	C	0.002	67	134	97
11	0.043	*	0.001	A	*	A	*	A	0.002	67	112	125
12	0.044	*	0.001	B	*	B	*	B	0.002	68	125	103
13	0.036	*	0.001	L	*	L	*	L	0.002	67	124	85
14	0.047	*	0.001	E	*	E	*	E	0.002	67	123	100
15	0.071	*	0.002		*		*		0.003	68	125	152
16	0.035	*	0.001		*		*		0.002	68	120	84
17	0.059	*	0.001		*		*		0.002	67	124	113
18	0.051	*	0.001		*		*		0.002	68	122	120
19	0.070	*	0.001		*		*		0.002	67	127	147
20	0.021	*	0.000		*		*		0.001	67	128	49
21	0.076	*	0.001		*		*		0.002	67	122	167
22	0.040	*	0.001		*		*		0.002	67	133	88
23	0.056	*	0.019		*		*		0.031	68	123	128
24	0.069	*	0.028		*		*		0.047	67	122	151
25	0.054	*	0.008		*		*		0.013	67	123	111
26	0.027	*	0.002		*		*		0.003	67	129	58
27	0.080	*	0.038		*		*		0.063	67	124	208
28	0.057	*	0.031		*		*		0.052	68	124	129
29	0.055	*	0.023		*		*		0.039	68	119	117
30	0.052	*	0.041		*		*		0.068	67	122	119
SUM	1.572	-	0.216	N.A.	*	N.A.	*	N.A.	0.359	-	-	3399
AVG	0.052	*	0.007	N.A.	*	N.A.	*	N.A.	0.012	67	125	113
NBS	Q302	N300	Q300	Q303	Q301	Q305	Q306	Q311	Q313	N305	N307	N308

* DENOTES UNAVAILABLE DATA.
@ DENOTES NULL DATA.
N.A. DENOTES NOT APPLICABLE DATA.

SOLAR HEATING AND COOLING DEMONSTRATION PROGRAM

MONTHLY REPORT
ENVIRONMENTAL SUMMARY

SITE: LIVING SYSTEMS (159-1) DAVIS, CALIFORNIA SO_AR/1046-79/04
REPORT PERIOD: APRIL,1979

DAY OF MONTH	TOTAL INSOLATION BTU/SQ.FT	DIFFUSE INSOLATION BTU/SQ.FT	AMBIENT TEMPERATURE DEG F	DAYTIME AMBIENT TEMP DEG F	RELATIVE HUMIDITY PERCENT	WIND DIRECTION DEGREES	WIND SPEED M.P.H.
1	1979	N	55	64	43	217	14
2	2000	O	57	68	49	227	8
3	1848	T	58	70	54	216	6
4	1854		59	70	59	0	2
5	1415	A	56	*	71	340	7
6	680	P	52	57	81	350	6
7	1989	P	57	68	69	232	7
8	1598	L	58	70	68	346	7
9	1819	I	56	66	50	228	8
10	1794	C	54	66	48	253	9
11	1384	A	60	70	59	345	5
12	1727	B	58	72	65	347	5
13	1908	L	60	71	63	*	4
14	1828	E	61	75	59	337	5
15	1705		62	74	55	342	4
16	540		55	59	67	336	10
17	992		53	58	64	287	7
18	1689		52	63	55	311	4
19	1810		53	66	52	*	3
20	1593		56	68	49	352	4
21	1450		59	71	50	327	4
22	759		56	63	64	337	8
23	1287		56	62	70	349	11
24	1534		56	67	62	227	5
25	1137		60	70	61	203	4
26	51		58	60	92	*	6
27	1847		60	68	65	321	5
28	1732		61	72	63	247	4
29	1018		60	71	69	339	4
30	1576		58	69	71	328	7
SUM	44544	N.A.	-	-	-	-	-
AVG	1485	N.A.	57	67	62	300	6
NBS ID	Q001		N113			N115	N114

* DENOTES UNAVAILABLE DATA.
@ DENOTES NULL DATA.
N.A. DENOTES NOT APPLICABLE DATA.

SOLAR HEATING AND COOLING DEMONSTRATION PROGRAM

MONTHLY REPORT
SITE SUMMARY

SITE: LIVING SYSTEMS (159-2)   DAVIS, CALIFORNIA   SOLAR/1046-79/04
REPORT PERIOD: APRIL,1979

SITE/SYSTEM DESCRIPTION:
THE LIVING SYSTEMS PASSIVE SOLAR SPACE HEATING SYSTEM PROVIDES SPACE HEATING FOR A 1700 SQUARE FOOT SINGLE FAMILY DWELLING. THE LARGE SOUTH-FACING WINDOW WALL AND CLERESTORY SKYLIGHT PERMIT DIRECT WINTER SUN TO ENTER THE HOUSE. SOLAR ENERGY THERMAL STORAGE IS PROVIDED BY BOTH WATER FILLED TUBES AND THE CONCRETE SLAB FLOOR. MOVABLE SHUTTERS AND INSULATING CURTAINS PROVIDE CAPABILITY TO REDUCE NIGHT HEAT LOSSES. SUMMER OVERHEAT PROTECTION IS PROVIDED BY ROOF OVERHANGS AND BY NATURAL VENTILATION. AUXILIARY SPACE HEAT IS PROVIDED BY A NATURAL GAS FURNACE.

GENERAL SITE DATA:

INCIDENT SOLAR ENERGY	10.348 MILLION BTU
	37904 BTU/SQ.FT.
COLLECTED SOLAR ENERGY	3.865 MILLION BTU
	14160 BTU/SQ.FT.
AVERAGE AMBIENT TEMPERATURE	57 DEGREES F
AVERAGE BUILDING TEMPERATURE	68 DEGREES F
ECSS SOLAR CONVERSION EFFICIENCY	0.36
ECSS OPERATING ENERGY	N.A. MILLION BTU
TOTAL SYSTEM OPERATING ENERGY	N.A. MILLION BTU
TOTAL ENERGY CONSUMED	3.687 MILLION BTU

SUBSYSTEM SUMMARY:

	HOT WATER	HEATING	COOLING	SYSTEM TOTAL
LOAD	N.A.	3.683	N.A.	3.683 MILLION BTU
SOLAR FRACTION	N.A.	100	N.A.	100 PERCENT
SOLAR ENERGY USED	N.A.	3.683	N.A.	3.683 MILLION BTU
OPERATING ENERGY	N.A.	N.A.	N.A.	N.A. MILLION BTU
AUX. THERMAL ENERGY	N.A.	0.000	N.A.	0.000 MILLION BTU
AUX. ELECTRIC FUEL	N.A.	N.A.	N.A.	N.A. MILLION BTU
AUX. FOSSIL FUEL	N.A.	0.000	N.A.	0.000 MILLION BTU
ELECTRICAL SAVINGS	N.A.	N.A.	N.A.	N.A. MILLION BTU
FOSSIL SAVINGS	N.A.	6.138	N.A.	6.138 MILLION BTU

SYSTEM PERFORMANCE FACTOR: 100.000

* DENOTES UNAVAILABLE DATA
@ DENOTES NULL DATA
N.A. DENOTES NOT APPLICABLE DATA

REFERENCE: USER'S GUIDE TO THE MONTHLY PERFORMANCE REPORT OF THE NATIONAL SOLAR DATA PROGRAM, FEBRUARY 28, 1978, SOLAR/0004-78/18

SOLAR HEATING AND COOLING DEMONSTRATION PROGRAM

MONTHLY REPORT
SITE SUMMARY

SITE: LIVING SYSTEMS (159-2) DAVIS, CALIFORNIA SOLAR/1046-79/04
REPORT PERIOD: APRIL,1979

SITE/SYSTEM DESCRIPTION:
THE LIVING SYSTEMS PASSIVE SOLAR SPACE HEATING SYSTEM PROVIDES SPACE HEATING FOR A 1700 SQUARE FOOT SINGLE FAMILY DWELLING. THE LARGE SOUTH-FACING WINDOW WALL AND CLERESTORY SKYLIGHT PERMIT DIRECT WINTER SUN TO ENTER THE HOUSE. SOLAR ENERGY THERMAL STORAGE IS PROVIDED BY BOTH WATER FILLED TUBES AND THE CONCRETE SLAB FLOOR. MOVABLE SHUTTERS AND INSULATING CURTAINS PROVIDE CAPABILITY TO REDUCE NIGHT HEAT LOSSES. SUMMER OVERHEAT PROTECTION IS PROVIDED BY ROOF OVERHANGS AND BY NATURAL VENTILATION. AUXILIARY SPACE HEAT IS PROVIDED BY A NATURAL GAS FURNACE.

GENERAL SITE DATA:

INCIDENT SOLAR ENERGY	10.917 GIGA JOULES
	470435 KJ/SQ.M.
COLLECTED SOLAR ENERGY	4.078 GIGA JOULES
	160799 KJ/SQ.M.
AVERAGE AMBIENT TEMPERATURE	14 DEGREES C
AVERAGE BUILDING TEMPERATURE	20 DEGREES C
ECSS SOLAR CONVERSION EFFICIENCY	0.36
ECSS OPERATING ENERGY	N.A. GIGA JOULES
TOTAL SYSTEM OPERATING ENERGY	N.A. GIGA JOULES
TOTAL ENERGY CONSUMED	3.885 GIGA JOULES

SUBSYSTEM SUMMARY:

	HOT WATER	HEATING	COOLING	SYSTEM TOTAL
LOAD	N.A.	3.885	N.A.	3.885 GIGA JOULES
SOLAR FRACTION	N.A.	100	N.A.	100 PERCENT
SOLAR ENERGY USED	N.A.	3.885	N.A.	3.885 GIGA JOULES
OPERATING ENERGY	N.A.	N.A.	N.A.	N.A. GIGA JOULES
AUX. THERMAL ENG	N.A.	0.000	N.A.	0.000 GIGA JOULES
AUX. ELECTRIC FUEL	N.A.	N.A.	N.A.	N.A. GIGA JOULES
AUX. FOSSIL FUEL	N.A.	0.000	N.A.	0.000 GIGA JOULES
ELECTRICAL SAVINGS	N.A.	N.A.	N.A.	N.A. GIGA JOULES
FOSSIL SAVINGS	N.A.	6.476	N.A.	6.476 GIGA JOULES

SYSTEM PERFORMANCE FACTOR: 100.000

* DENOTES UNAVAILABLE DATA
@ DENOTES NULL DATA
N.A. DENOTES NOT APPLICABLE DATA

REFERENCE: USER'S GUIDE TO THE MONTHLY PERFORMANCE REPORT OF THE NATIONAL SOLAR DATA PROGRAM.FEBRUARY 28,1978, SOLAR/0004-78/18

SOLAR HEATING AND COOLING DEMONSTRATION PROGRAM

MONTHLY REPORT
COLLECTOR ARRAY PERFORMANCE

SITE: LIVING SYSTEMS (199-2)   DAVIS, CALIFORNIA   SOLAR/1046-79/04
REPORT PERIOD: APRIL,1979

DAY OF MONTH	INCIDENT SOLAR ENERGY MILLION BTU	OPERATIONAL INCIDENT ENERGY MILLION BTU	COLLECTED SOLAR ENERGY MILLION BTU	DAYTIME AMBIENT TEMP DEG F	COLLECTOR ARRAY EFFICIENCY
1	0.481	0.098	N	64	N
2	0.481	0.248	O	66	O
3	0.444	0.223	T	70	T
4	0.447	0.236		72	
5	0.338	0.167	A	*	A
6	0.153	0.015	P	57	P
7	0.466	0.285	P	62	P
8	0.378	0.172	L	70	L
9	0.432	0.215	I	66	I
10	0.426	0.315	C	66	C
11	0.326	0.169	A	70	A
12	0.410	0.136	B	72	B
13	0.446	0.150	L	71	L
14	0.430	0.167	E	75	E
15	0.401	0.226		74	
16	0.116	0.051		59	
17	0.227	0.127		58	
18	0.379	0.127		63	
19	0.415	0.231		66	
20	0.369	0.066		68	
21	0.332	0.094		71	
22	0.173	0.064		63	
23	0.291	0.163		62	
24	0.345	0.192		67	
25	0.259	0.098		70	
26	0.009	0.001		60	
27	0.411	0.060		58	
28	0.386	0.145		72	
29	0.225	0.125		71	
30	0.352	0.081		69	
SUM	10.348	4.436	3.865	-	-
AVG	0.345	0.148	N.A.	67	N.A.
NBSID	Q001		Q100		N100

* DENOTES UNAVAILABLE DATA.
@ DENOTES NULL DATA.
N.A. DENOTES NOT APPLICABLE DATA.

SOLAR HEATING AND COOLING DEMONSTRATION PROGRAM

MONTHLY REPORT
SPACE HEATING SUBSYSTEM

SITE: LIVING SYSTEMS (159-2)   DAVIS, CALIFORNIA   SOLAR/1046-79/04
REPORT PERIOD: APRIL,1979

DAY OF MON.	SPACE HEATING LOAD MILLION BTU	SOLAR FR.OF LOAD PCT	SOLAR ENERGY USED MILLION BTU	OPER ENERGY MILLION BTU	AUX THERMAL USED MILLION BTU	AUX ELECT FUEL MILLION BTU	AUX FOSSIL FUEL MILLION BTU	ELECT ENERGY SAVINGS MILLION BTU	FOSSIL ENERGY SAVINGS MILLION BTU	BLDG TEMP DEG. F	AMB TEMP DEG. F
1	0.086	100	0.086	N	0.000	N	0.000	N	0.144	65	55
2	0.104	100	0.104	O	0.000	O	0.000	O	0.174	66	57
3	0.105	100	0.105	T	0.000	T	0.000	T	0.175	68	58
4	0.106	100	0.106		0.000		0.000		0.177	69	59
5	0.148	100	0.148	A	0.000	A	0.000	A	0.247	70	56
6	0.163	100	0.163	P	0.000	P	0.000	P	0.272	67	52
7	0.110	100	0.110	P	0.000	P	0.000	P	0.184	67	57
8	0.127	100	0.127	L	0.000	L	0.000	L	0.212	69	58
9	0.143	100	0.143	I	0.000	I	0.000	I	0.238	68	56
10	0.163	100	0.163	C	0.000	C	0.000	C	0.272	67	54
11	0.102	100	0.102	A	0.000	A	0.000	A	0.169	70	60
12	0.127	100	0.127	B	0.000	B	0.000	B	0.212	69	58
13	0.114	100	0.114	L	0.000	L	0.000	L	0.190	70	60
14	0.095	100	0.095	E	0.000	E	0.000	E	0.159	70	61
15	0.087	100	0.087		0.000		0.000		0.145	71	62
16	0.176	100	0.176		0.000		0.000		0.293	69	55
17	0.177	100	0.177		0.000		0.000		0.295	67	53
18	0.162	100	0.162		0.000		0.000		0.270	66	52
19	0.140	100	0.140		0.000		0.000		0.234	66	53
20	0.121	100	0.121		0.000		0.000		0.202	67	56
21	0.112	100	0.112		0.000		0.000		0.187	68	59
22	0.136	100	0.136		0.000		0.000		0.227	69	56
23	0.147	100	0.147		0.000		0.000		0.244	68	56
24	0.127	100	0.127		0.000		0.000		0.211	68	56
25	0.092	100	0.092		0.000		0.000		0.154	68	60
26	0.104	100	0.104		0.000		0.000		0.174	68	58
27	0.091	100	0.091		0.000		0.000		0.151	69	60
28	0.095	100	0.095		0.000		0.000		0.159	69	61
29	0.098	100	0.098		0.000		0.000		0.163	70	60
30	0.122	100	0.122		0.000		0.000		0.204	69	58
SUM	3.683	-	3.683	N.A.	0.000	N.A.	0.000	N.A.	6.138	-	-
AVG	0.123	100	0.123	N.A.	0.000	N.A.	0.000	N.A.	0.205	68	57
NBS	Q402	N400	Q400	Q403	Q401		Q410	Q415	Q417	N406	N113

* DENOTES UNAVAILABLE DATA.
@ DENOTES NULL DATA.
N.A. DENOTES NOT APPLICABLE DATA.

SOLAR HEATING AND COOLING DEMONSTRATION PROGRAM

MONTHLY REPORT
ENVIRONMENTAL SUMMARY

SITE: LIVING SYSTEMS (159-2) DAVIS, CALIFORNIA SOLAP/1046-79/04
REPORT PERIOD: APRIL,1979

DAY OF MONTH	TOTAL INSOLATION BTU/SQ.FT	DIFFUSE INSOLATION BTU/SQ.FT	AMBIENT TEMPERATURE DEG F	DAYTIME AMBIENT TEMP DEG F	RELATIVE HUMIDITY PERCENT	WIND DIRECTION DEGREES	WIND SPEED M.P.H.
1	1760	N	55	64	43	217	14
2	1763	O	57	68	49	227	8
3	1625	T	58	70	54	216	6
4	1639		59	70	59	0	2
5	1238	A	56	*	71	340	7
6	562	P	52	57	81	350	6
7	1707	P	57	58	69	232	7
8	1384	L	58	70	68	346	7
9	1584	I	56	66	50	228	8
10	1562	C	54	66	48	253	9
11	1192	A	60	70	59	345	5
12	1503	B	58	72	65	347	5
13	1635	L	60	71	63	*	4
14	1575	E	61	75	59	337	5
15	1468		62	74	55	342	4
16	425		55	59	67	336	10
17	833		53	58	64	287	7
18	1386		52	63	56	311	4
19	1519		53	66	52	*	3
20	1352		56	68	49	352	4
21	1214		59	71	50	337	4
22	635		56	67	64	337	8
23	1066		56	62	70	349	11
24	1265		56	67	62	227	5
25	949		60	70	61	203	4
26	31		58	60	92	*	6
27	1506		60	68	65	321	5
28	1413		61	72	63	247	4
29	823		60	71	69	339	4
30	1289		58	69	71	328	7
SUM	37904	N.A.	-	-	-	-	-
AVG	1263	N.A.	57	67	62	300	6
NBS ID	Q001		N113			N115	N114

* DENOTES UNAVAILABLE DATA.
@ DENOTES NULL DATA.
N.A. DENOTES NOT APPLICABLE DATA.

SOLAR HEATING AND COOLING DEMONSTRATION PROGRAM

MONTHLY REPORT
PASSIVE SPACE HEATING

SITE: LIVING SYSTEMS (159-2)   DAVIS, CALIFORNIA   SOLAR/1046-79/04
REPORT PERIOD: APRIL,1979

DAY OF MON	SPACE HEATING LOAD MILLION BTU	SOLAR ENERGY USED MILLION BTU	CHANGE IN STORE ENERGY MILLION BTU	AVERAGE STORAGE TEMP DEG F	DIRECT SOLAR UTIL EFFIC	AUX THERMAL USED MILLION BTU	BLDG TEMP DEG F	AMB TEMP DEG F	WIND AVG SPEED MPH	WIND AVG DIR DEG	SOLAR FR LOAD PER CENT
1	0.086	0.086	-0.035	66.4	0.179	0.000	65	55	14.3	217	100
2	0.104	0.104	0.067	66.8	0.217	0.000	66	57	7.7	227	100
3	0.105	0.105	0.073	67.7	0.237	0.000	68	58	5.7	216	100
4	0.106	0.106	0.067	68.4	0.238	0.000	69	59	1.7	0	100
5	0.148	0.148	0.036	69.4	0.478	0.000	70	56	6.8	340	100
6	0.163	0.163	-0.107	68.6	1.065	0.000	67	52	6.3	350	100
7	0.110	0.110	0.021	67.9	0.237	0.000	67	57	7.4	232	100
8	0.127	0.127	0.053	68.6	0.337	0.000	69	58	7.1	346	100
9	0.142	0.142	-0.019	69.0	0.330	0.000	68	56	7.8	228	100
10	0.163	0.163	-0.010	68.6	0.382	0.000	67	54	8.6	253	100
11	0.101	0.101	0.066	69.1	0.312	0.000	70	60	4.9	345	100
12	0.127	0.127	0.002	69.5	0.311	0.000	69	58	5.1	347	100
13	0.114	0.114	0.017	69.4	0.256	0.000	70	60	4.0	*	100
14	0.095	0.095	0.012	69.7	0.221	0.000	70	61	4.7	337	100
15	0.086	0.086	0.043	70.0	0.217	0.000	71	62	4.1	342	100
16	0.175	0.175	-0.090	69.7	1.516	0.000	69	55	10.2	336	100
17	0.176	0.176	-0.048	68.7	0.778	0.000	67	53	7.0	287	100
18	0.162	0.162	-0.039	67.9	0.428	0.000	66	52	3.6	311	100
19	0.140	0.140	0.002	67.7	0.338	0.000	66	53	3.3	*	100
20	0.121	0.121	-0.004	67.8	0.329	0.000	67	56	3.8	352	100
21	0.112	0.112	0.014	67.7	0.339	0.000	68	59	3.6	337	100
22	0.136	0.136	-0.015	68.0	0.785	0.000	69	56	7.7	337	100
23	0.146	0.146	0.000	67.7	0.504	0.000	68	56	10.5	349	100
24	0.126	0.126	0.038	68.1	0.367	0.000	68	56	4.9	227	100
25	0.092	0.092	0.015	68.2	0.357	0.000	68	60	3.8	203	100
26	0.104	0.104	-0.046	68.3	12.168	0.000	68	58	6.2	*	100
27	0.090	0.090	0.027	67.9	0.220	0.000	69	60	5.4	321	100
28	0.095	0.095	0.037	68.2	0.247	0.000	69	61	3.6	247	100
29	0.097	0.097	0.011	68.8	0.434	0.000	70	60	4.0	339	100
30	0.122	0.122	-0.009	68.6	0.347	0.000	69	58	6.5	328	100
SUM	3.682	3.682	0.182	-	-	0.000	-	-	-	-	-
AVG	0.122	0.122	0.006	68.4	0.356	0.000	68	57	6.0	300	100
NBS	Q402	Q400	Q202			Q401	N405	N113	N114	N115	N400

* DENOTES UNAVAILABLE DATA.
@ DENOTES NULL DATA.
N.A. DENOTES NOT APPLICABLE DATA.

SOLAR HEATING AND COOLING DEMONSTRATION PROGRAM

MONTHLY REPORT
PASSIVE SYSTEM ENVIRONMENT

SITE: LIVING SYSTEMS (159-2) DAVIS, CALIFORNIA SOLAR/1046-79/04
REPORT PERIOD: APRIL,1979

DAY OF MON	BUILDING COMFORT ZONE 1	BLDG COMF ZONE 2	BUILDING TEMP MIDNIGHT DEG F	BUILDING TEMP 6 AM DEG F	BUILDING TEMP NOON DEG F	BUILDING TEMP 6 PM DEG F	INTERIOR RELATIVE HUMIDITY PERCENT	AMB TEMP DEG F	DAYTIME AMB TEMP DEG F	INCIDENT SOLAR ENERGY MILLION BTU	AVG STOR TEMP DEG F
1	66	66	65	62	64	67	33	55	64	0.481	66
2	67	67	67	62	66	70	35	57	68	0.481	67
3	68	68	69	63	67	72	38	58	70	0.444	68
4	69	70	71	64	70	73	42	59	70	0.447	68
5	70	70	69	66	71	72	42	56	*	0.338	69
6	68	69	66	66	67	68	42	52	57	0.153	69
7	68	68	68	62	67	72	41	57	68	0.466	68
8	69	69	69	65	71	73	41	58	70	0.378	69
9	69	69	67	65	67	70	37	56	66	0.432	69
10	68	68	68	63	67	70	35	54	66	0.426	69
11	70	70	69	66	72	75	39	60	70	0.326	69
12	70	70	70	65	71	73	40	58	72	0.410	69
13	70	70	70	65	70	75	42	60	71	0.446	69
14	70	71	69	66	72	75	39	61	75	0.430	70
15	70	71	72	66	72	77	37	62	74	0.401	70
16	69	70	67	68	69	71	38	55	59	0.116	70
17	68	69	66	65	69	70	38	53	58	0.227	69
18	68	68	66	63	67	70	36	52	63	0.379	68
19	68	68	67	62	67	71	36	53	66	0.415	68
20	68	68	68	63	67	72	37	56	68	0.369	68
21	68	68	70	61	67	74	36	59	71	0.332	68
22	68	69	67	67	69	70	39	55	63	0.173	68
23	68	68	68	65	68	70	41	56	62	0.291	68
24	68	69	68	65	69	72	41	56	67	0.345	68
25	69	69	71	65	68	71	42	60	70	0.259	68
26	68	69	*	68	67	68	47	58	60	0.009	68
27	68	69	69	65	70	73	48	60	68	0.411	68
28	69	69	71	65	70	74	45	61	72	0.386	68
29	69	70	69	67	71	73	45	60	71	0.225	69
30	69	70	69	66	69	71	44	58	69	0.352	69
SUM	-	-	-	-	-	-	-	-	-	10.348	-
AVG	69	69	68	65	69	72	40	57	67	0.345	68
NBS								N113			

* DENOTES UNAVAILABLE DATA.
@ DENOTES NULL DATA.
N.A. DENOTES NOT APPLICABLE DATA.